QUALITY WORKS.

Introducing a Hydrolytically Stable, Low Toxicity Fire-Resistant Hydraulic Fluid for Power Stations

STLE Commercial Marketing Forum 2018

David Stonecipher
Director, Business Development

LANXESS
Energizing Chemistry

Agenda

- The New LANXESS
- Power Generation Need for Fire Resistance
- Not All Fire-Resistant Fluids Are Created Equal
- REOLUBE® Hydraulic Fluids
- Regulatory Change is Fast Approaching
- Low Toxicity REOLUBE® Hydraulic Fluid
- Summary

LANXESS – A Global Specialty Chemicals Company

LANXESS
Energizing Chemistry

Specialty chemicals company

- Spin-off from Bayer in 2004
- Specialty chemicals portfolio:
  engineered plastics, advanced intermediates and specialty chemicals

Global success story

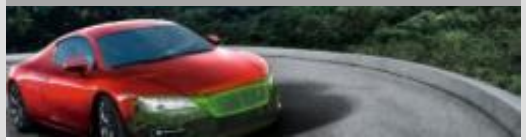
- 74 sites worldwide
- Approximately 19,200 employees in 25 countries
- Global sales of EUR ~9.72 billion in 2017

Strategy of profitability and resilience

- Strengthening of leading position in medium-sized markets
- Expanding global footprint
- Acquired Chemtura in April 2017

LANXESS

LANXESS – Lubricant Additives is a Key Growth Platform

Engineering Materials	Advanced Intermediates	Performance Chemicals	Specialty Additives
			
▪ High Performance Materials ▪ Urethane Systems	▪ Advanced Industrial Intermediates - Organometallics ▪ Saltigo	▪ Material Protection Products ▪ Inorganic Pigments ▪ Leather ▪ Liquid Purification Technologies	▪ **Additives** – **Lubricant Additives** – Polymer Additives ▪ Rhein Chemie

Group Functions and Countries

Business unit set up fosters dedication and entrepreneurship

Lubricant Additives – Integrated Portfolio for Wide Variety of Transportation and Industrial Applications

Overview

- **Employees:** ~ 800 worldwide
- **Production sites:** 14
- **Products:** ~ 660 different products
- **Customers:** More than 800 worldwide
- **Applications:**
  - Automotive
  - Marine
  - Aerospace & defense
  - Power Generation
  - Refrigeration
  - Metal Working
  - General Industrial









Lubricants Additives Business offers an integrated portfolio for lubricants

Lubricant Additives – Full Value Chain Solutions

Synthetic Base Fluids	▪ High Viscosity PAOs ▪ Specialty Esters ▪ Phosphate Esters ▪ Ester-Functionalized PAOs (WTP 40)	
Additive Components and Packages	▪ Aminic Antioxidants ▪ Detergents & Corrosion Inhibitors ▪ Extreme Pressure, Anti-Wear Additives ▪ Water-Miscible Additives ▪ Industrial Additive Packages	
Formulated Lubricants	▪ Fire-resistant Hydraulic Fluids ▪ Refrigeration Fluids ▪ Aerospace & Defense Fluids ▪ General Industrial Fluids ▪ High-performance Greases	

6

Lubricant Additives – Extensive Global Manufacturing, Technology and Sales Network

Headquarters: Middlebury, CT, USA

Manufacturing:

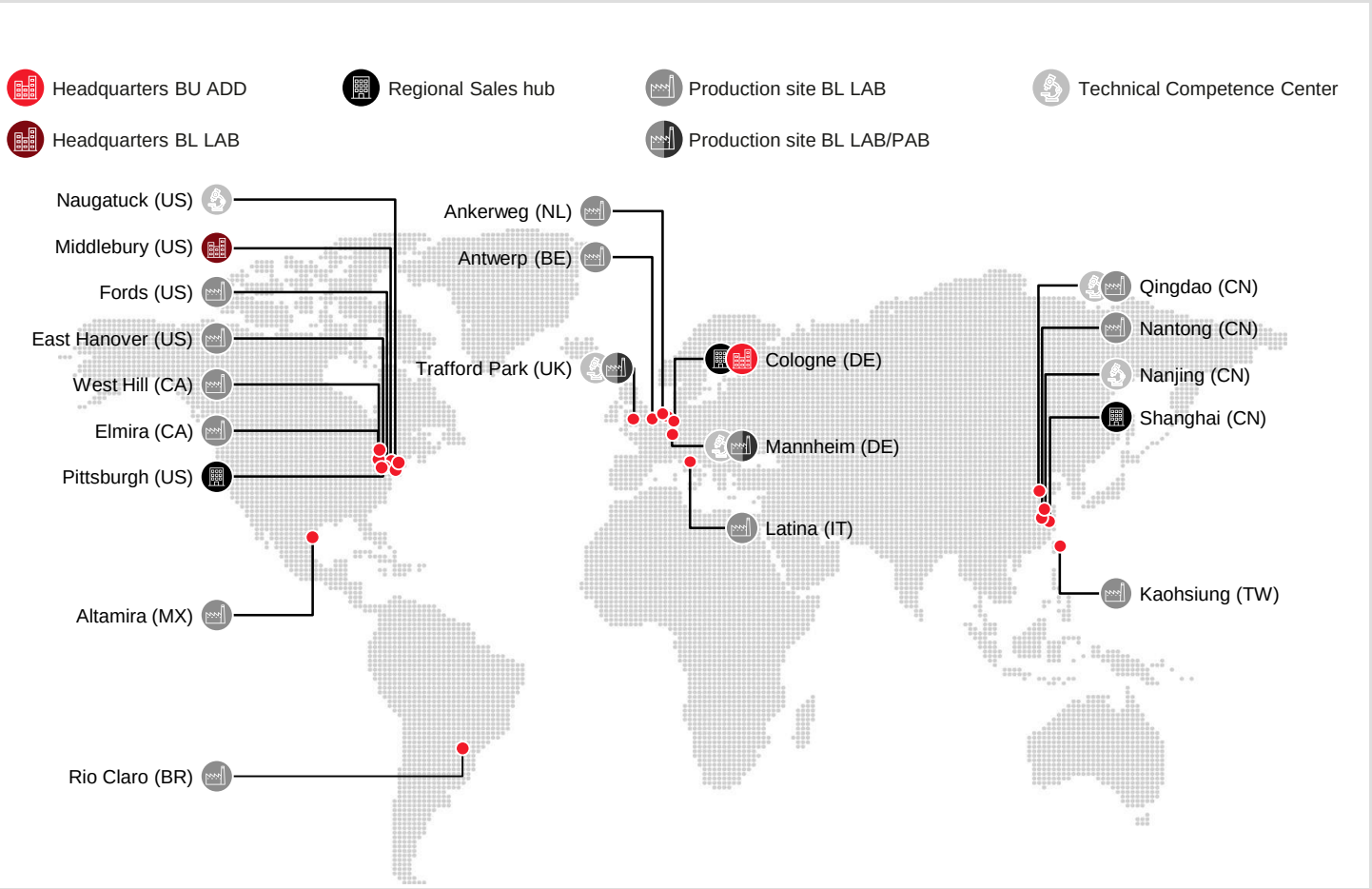
- 14 production sites in 11 countries

Technical Competence Centers:

- Mannheim, Germany
- Qingdao, China
- Trafford Park, UK
- Nanjing, China
- Naugatuck, CT, USA

Regional Sales Hubs:

- Cologne, Germany
- Pittsburgh, PA, USA
- Shanghai, China



Power Generation Need for Fire Resistance

- Every year there are serious losses from fire in power stations
- Reported that 75% of fires originate in turbine oil systems → 700 fires reported from 1991-2005
- Further reported that 50% of these fires originate from the hydraulic system
- Fire impacts
  - Loss of life
  - Loss of equipment
  - Loss of production
- It is estimated that the use of fire-resistant hydraulic fluids save 500 lives per year
- The use of fire-resistant hydraulic fluids can reduce insurance premiums

Electrohydraulic Control (EHC) Systems

- EHC fluids typically are non-aqueous, and are used in power turbine control systems to govern the steam supply to the turbine generators
- The EHC system is required to react extremely quickly (milliseconds) in order to shut off steam to prevent a ‘runaway’ turbine
- A fluid leak or spray from a pressurized hydraulic system coming into contact with hot surfaces such as super-heated steam pipes is a considerable fire risk
- Steam temperatures can range from 300˚C to over 600˚C with ultra-supercritical power plants
- These temperatures are well above the ignition point of most hydraulic fluids – even synthetic based products
- The fluid choice needs to be made with safety in mind...

Not All Fire-Resistant EHC Fluids Are Created Equal

- Several different types of EHC hydraulic fluids are fully approved by FM Global Group under Standard 6930 (Industrial Fluids) and carry the FM kitemark
  - Phosphate esters
  - Polyol esters
  - Polyalkylene glycols (PAG)

- However not all of these fluids have the same level of fire performance

- Take a look... Show video

REOLUBE® HYD for primary metals applications

REOLUBE® Turbofluids for power generation applications

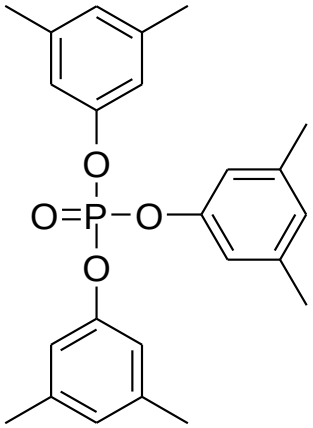
REOLUBE® Turbofluids

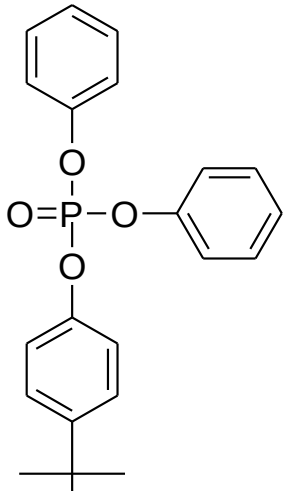
- A range of fire resistant hydraulic fluids designed specially for the operation of EHC systems
- Enable power station operators to avoid injuries and lost business due to fires, and to achieve cost savings in maintenance, equipment and insurance
- Meet the ISO 12922 category HFDR designation for less flammable fluids and additionally meet ISO 10050 for triarylphosphate ester turbine control fluids
- Approved by numerous steam generator OEMs for their use in their equipment and must be used to maintain the equipment warranty (GE, Siemens, Alstom, Mitsubishi, Chinese National)
- Manufactured to very low acid and water content and purified to remove particulates and electrically conductive impurities
- Formulated with additives to assure oxidative stability, metals compatibility, foam and air entrainment performance

LANXESS

REOLUBE® Turbofluid Base Stocks

Tri-Xylyl Phosphate TXP





Tertiary-Butylphenol Phosphate TBPP

Type	Raw Material Source	Comments
Xylyl	Natural from coal tars	Mixture of isomers
Tert-butyl	Synthetic from phenol and isobutene	Mixture of isomers

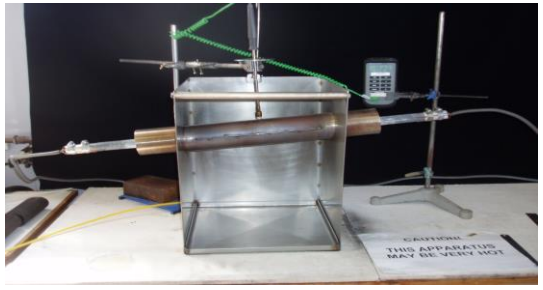
LANXESS

REOLUBE® Turbofluid Grades

ISO Viscosity at 40°C	Base Fluid		Application
	Trixylylphosphate (TXP)	t-butylated triphenylphosphate (TBPP)	
32		REOLUBE® Turbofluid 32B GT	Bearing lubrication for stationary gas turbines or combined cycle and steam turbine units
46	REOLUBE® Turbofluid 46XC	REOLUBE® Turbofluid 46B	Hydraulic fluid in power plant steam turbine EHC systems
46	REOLUBE® 46RS		Customized formulation for Russia turbine OEM LMZ's nuclear and thermal units

Important EHC Fluid Fire Resistance Specifications

Parameter	Test	Typical Limit	Comments
Hot manifold ignition	ISO 20823	Min 700°C ignition temp.	Duplicates a fluid leak dropping onto a hot surface
Wick flame persistence	ISO 14935	Max 60 sec avg. burn time	Tests the self extinguishing properties of the fluid
Spray ignition persistence	ISO 15029-1	Max 30 sec avg. burn time	Tests flammability characteristics of a high pressure fluid leak



ISO 20823

ISO 14953

ISO 15029-1

ISO 20823 Hot Manifold Ignition Test

Phosphate esters are the most difficult to ignite and burn

Fluid	Ignition °C	Flaming Drips to Tray?	Flames in Tray?
Phosphate Ester (Reolube® TF 46XC)	741	No	No
Phosphate Ester (Reolube® TF 46B)	726	No	No
	700°C		
Polyol Ester	495	Yes	Yes
PAG	458	Yes	Yes
PAO/Ester	474	Yes	Yes
Mineral oil (Group I)	444	Yes	Yes

- A 10 ml test portion is dropped from a set height and rate (40-60 s) onto a 700°C tube, or another temperature in series
- The resulting spray is examined for flash or burn both on the tube and after dripping from the tube onto the tray below
- Temperature varies along the length of the tube; Ignition temperature is measured in the center (hottest area)

ISO 14935 Wick Flame Persistence Test

Self-extinguishing phosphate esters are the only fluid able to pass this test

Fluid	Pass <60 s Fail >60 s	30 sec Flame Application Average Burn time, s
Phosphate ester (Reolube® TF 46XC)	Pass	2.2
Phosphate ester (Reolube® TF 46B)	Pass	1.2
Polyol ester	Fail	>60
PAG	Fail	>60
PAO Ester	Fail	>60
Mineral oil (Group I)	Fail	>60

- A non-flammable aluminosilicate board is soaked in the test fluid and placed in a fluid reservoir with an exposed edge
- A flame is applied to the exposed edge and the flame persistence time is measured after removal of the igniting flame
- A total of six determinations is carried out and averaged for five different periods of flame application (2, 5, 10, 20, 30 s)

ISO 15029-1 Spray Ignition Flame Persistence Test

Self-extinguishing phosphate esters are the only fluid able to pass this test

Fluid	Pass <30 s Fail >30 s	Maximum Burn Time, s
Phosphate ester (Reolube® TF 46XC)	Pass	3
Phosphate ester (Reolube® TF 46B)	Pass	8
Polyol ester	Fail	125
PAG	Fail	134
PAO Ester	Fail	124
Mineral oil (Group I)	Fail	130

- A sample of fluid is pressurized and heated to a set pressure and temperature, and then atomized through a nozzle
- The spray produced is ignited with an oxyacetylene test flame of specified energy in succession at various points along the whole length of the spray pattern
- After ignition, the test flame is withdrawn, and the time is measured that the flame continues to burn

Regulatory Change is Fast Approaching

It is likely use of TXP-based fluids will be banned in the EU sometime after 2020

- Trixylylphosphates (TXP) including REOLUBE® Turbofluid 46XC have been categorized as Reprotox Hazard Category 1B, GHS code H360F (may damage fertility)
- TXP is also now on the European REACH list of candidates for Substances of Very High Concern (SVHC) and is on the draft Annex XIV
- We expect Annex XIV to be published in the immediate future with TXP included
- After inclusion in Annex XIV there are 21 months to apply for authorisation for use
- The sunset date for TXP will then be the latest application date plus 18 months
- It is very likely the use of TXP (non-authorized) will be banned in the EU sometime after 2020

Low Toxicity REOLUBE® Turbofluid 46B

REOLUBE® 46B provides an excellent alternative to TXP grades

- LANXESS is committed to providing safer alternatives to existing products as possible
- Tert-butylphenylphosphate (TBPP) grades such as REOLUBE® Turbofluid 46B are not classified as reprotoxins and provide an excellent alternative to TXP grades
- REOLUBE® Turbofluid 46B has been used successfully in power plants for many years
- Recently, specifications for REOLUBE® Turbofluid 46B have been tightened and the product is now designed to offer comparable performance to REOLUBE® Turbofluid 46XC while eliminating safety concerns

Performance Comparison

Fluid Type	Product Safety	Air Entrainment	Foaming Tendency	Water Separation	Volume Resitivity	Hydrolytic Stability	Oxidative Stability
TXP (46XC)	Moderate	Excellent	Excellent	Excellent	Excellent	Excellent	Good
TBPP (46B)	Excellent	Good	Excellent	Excellent	Excellent	Good	Excellent

REOLUBE® Turbofluid 46B and 46XC Typical Values

Test	Method	Units	Reolube® Turbofluid 46B	Reolube® Turbofluid 46XC
Air entrainment	ISO 9120	min	5	1
Foam, tendency/stability	ISO 6247	ml	10/0	10/0
Volume resistivity	IEC 60247	Mohm/m	450	682
Acid number	ISO 6619	mgKOH/g	0.05	0.01
Water content	ISO 760	%w/w	0.04	0.03
Kinematic viscosity 40°C	ISO 3104	mm^2/s	44.5	45.2
Pour point	ISO 3016	°C	-24	-24
Water separation	ISO 6614	min	5	5
Ox stability, acid change	DIN EN14832	mg KOH/g	0.05	0.14

Fluid Maintenance – Preventing Hydrolysis is Key

- Properly maintained, REOLUBE® Turbofluids can remain in good working condition for 10 years or longer
- The key maintenance goal is to prevent hydrolysis by maintaining low water and acid content
- Any hydrolysis will increase acidity, causing formation of varnish and deposit precursors
  - Water can be removed by vacuum drying
  - Acid by-products can be removed by solids treatment using ion exchange resin, Fuller's earth or alumina
- Particulate contamination is removed by filtration
- Use of hydrolytically stable fluids in addition to proper fluid management practices is key to achieving unit maintenance and operating objectives

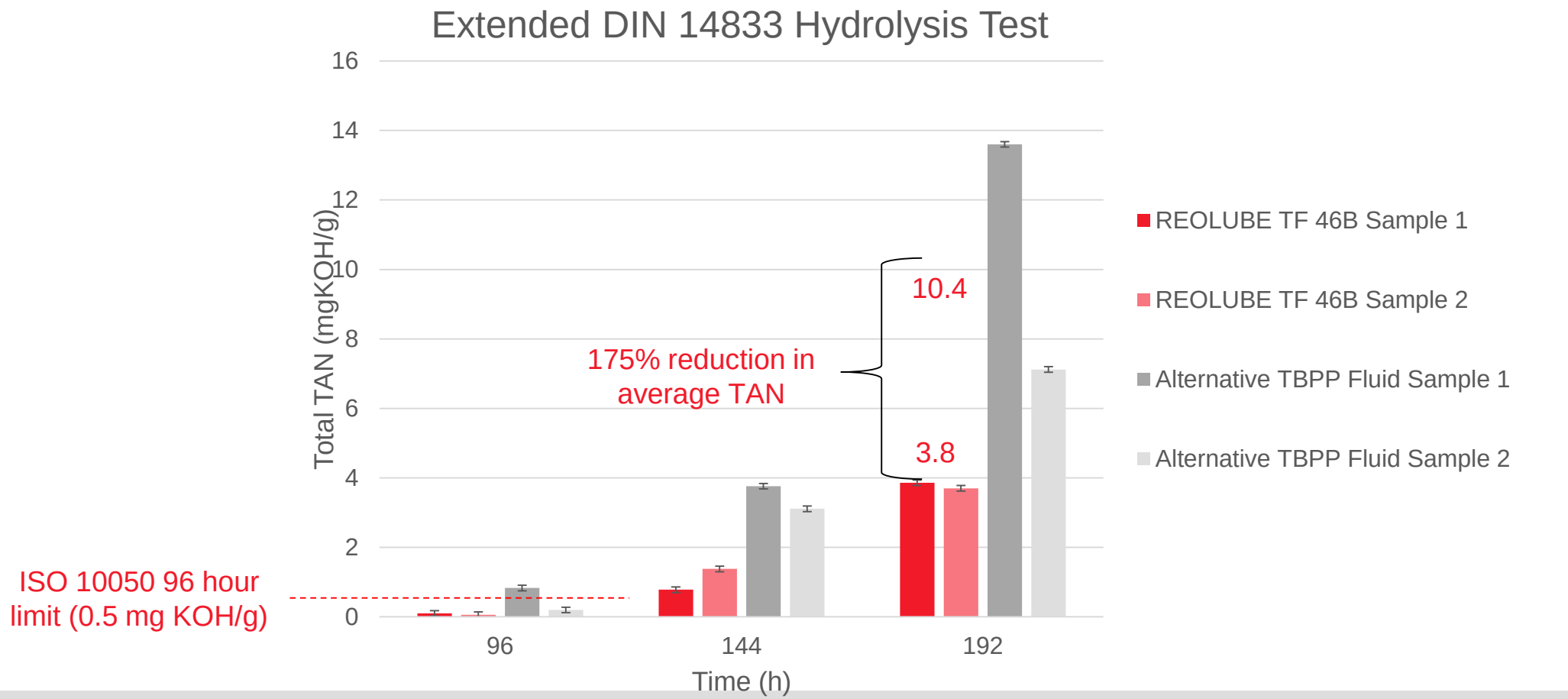
LANXESS

Hydrolytic Stability Test Method

- Use DIN 14833 test standard “Determination of the Hydrolytic Stability of Fire-resistant Phosphate Ester Fluids”
- Compare the hydrolysis performance of REOLUBE® Turbofluid 46B with an alternative tert-butylphenylphosphate (TBPP) EHC fluid available on the market
- The test severity was increased by extending the test running time from 96 hrs to 192 hours
- Test methodology
  - 300g of sample was heated with 100g of water at 85°C
  - Samples were taken at 96h, 144h and 192h
  - The TAN of the fluid and water was measured and the sum of the change in TAN of the fluid and water is reported
  - The ISO 10050 limit for this parameter after 96 hrs is 0.5 mg KOH/g
  - Two separate batches of each product were tested

LANXESS

REOLUBE® Turbofluid 46B Exhibits Superior Hydrolytic Stability Compared to an Alternative Fluid



Summary

- The Power Generation industry requires fire-resistant fluids in steam turbine EHC systems
- Phosphate ester-based fluids provide the highest level of fire-resistance of all non-aqueous fluids
- REACH hazard classification changes will drive a move to butylated phosphate ester-based hydraulic fluids
- REOLUBE® Turbofluid 46B offers a lower toxicity solution while providing better hydrolytic stability than an alternative butylated fluid
  - This helps to extend fluid life, reduce maintenance costs, minimize unit downtime and improve operating efficiency for power stations

LANXESS

Energizing Chemistry

Booth Number 127 & 129

Contact: David Stonecipher, david.stonecipher@lanxess.com, +1 440-522-8405